Slip Rate Studies Along The Sierra Madre-Cucamonga Fault System Using Geomorphic And Cosmogenic Surface Exposure Age Constraints: Collaborative Research with Central Washington University and William Lettis & Associates, Inc.

NEHRP External Grant Award Number 03HQGR0084

Charles M. Rubin[1] and Scott C. Lindvall[2]

[1]Central Washington University, 400 University Avenue, Ellensburg, WA 98926
509.963-2827; 509.963-1109 (fax), charlier@geology.cwu.edu
[2]William Lettis & Associates, Inc., 28470 Avenue Stanford, Suite 120, Valencia, CA 91351

Program Element III. Research on earthquake occurrence, physics and effects

Key Words: Paleoseismology, rupture characteristics, trench investigations, Quaternary fault behavior

Investigations Undertaken

This project is designed to provide a reliable slip rate estimate for the Sierra Madre-Cucamonga (SMC) fault system that bounds the southern margin of the San Gabriel Mountains (Figure 1). We proposed to (1) produce digital elevation models using the early 1920's USGS 6 minute topographic map series (5 foot contour intervals), (2) produce detailed maps of fault scarps and Quaternary geomorphic surfaces, (3) determine the age of these surfaces using cosmogenic surface exposure age dating techniques, and (4) calculate uplift rates and slip rates across the SMC fault system in the San Fernando and San Gabriel Valleys.

Our study included the following specific tasks:
Task 1: Expand earlier tectonic geomorphic analysis and mapping.
Task 2: Sample collection
Task 3: Cosmogenic dating
Task 4: Determine minimum uplift and dip-slip rates across the fault zone

During the past year, we have completed sampling and cosmogenic dating of surface samples collected from the abandoned geomorphic surfaces at three locations (Pacoima Wash, Lopez Canyon, and Wilson Canyon) along the 1971 San Fernando surface rupture and Day Canyon fan along the Cucamonga fault (Figure 1).

Pacomia Wash area

CWU graduate student, Jake Horner, processed and analyzed Be and Al isotopes at the Center for Accelerator Mass Spectrometry at LLNL from samples collected from alluvial surfaces in the

Pacoima Wash area (Figure 2). These samples help constrain fault slip rates along the San Fernando segment of the Sierra Madre fault system. Three quartz-rich cobbles from the active Pacoima Wash yield modern ^{10}Be and ^{26}Al ages, which indicate zero inheritance from the source area. Preliminary analyses of using ^{10}Be and ^{26}Al surface dating methods on alluvial cobbles from the Qt4 Pacoima Wash surface of Lindvall et al. (1995) yield surface exposure ages of 33,240 ±1564 yrs, 31,195 ±1287, and 31,024 ±1073 (Figure 2). This gives a mean surface exposure age 31,561 ± 729 years. The minimum vertical separation across Qt4 surface includes the 1971 surface rupture and two older scarps that offset Qt2-Qt5 is 27 m ± 1m.

Based on 27 m of vertical separation across multiple fault strands along Pacomia Wash, and a mean surface age of 31,561± 729 for the Qt4 surface, we estimate a vertical uplift rate across the Sylmar fault segment of 0.86 ± 0.04 mm/yr. Field observations of the surface rupture produced by the San Fernando earthquake indicate that rupture near the ground surface occurred on a 45° dipping fault plane (Kamb et al, 1971). Assuming an average fault dip of about 45° for fault strands 1, 2, and 3, combined with an uplift rate of 0.86 ± 0.04 mm/yr, yields a dip-slip rate of 1.2 ± 0.2 mm/yr across the Sylmar fault zone, which is similar to the dip-slip rate obtained by Lindvall et al. (1995) using soil age estimates.

Lopez Canyon fan

We have sampled, processed, and analyzed cobbles from the Lopez Canyon fan, located just west of the Lopez Canyon drainage, where alluvial deposits unconformably overlie Plio-Pleistocene Saugus Formation (Figure 3). Despite extensive surface degradation, detailed geomorphic analysis and field mapping has delineated two southward-facing topographic lineaments that trend northwest, forming parallel scarps (S4 and S5 Figure 3). A road cut through scarp 5 exposes faulted alluvium across a fault plane dipping about 45º north. Due to extensive dissection of the Lopez Canyon fan surface, our sampling efforts were concentrated near two portions of the fan that display the best-preserved surface morphology. Many cobbles exposed at these locations are heavily weathered and or fragmented, limiting our analyses to only a few suitable samples.

Analysis of the fan morphology, degree of soil development and topographic location, we agreed with earlier assessments by Wills and Hitchcock (1999) and Dibblee (1991) that the relative age of the fan surface is much older than the oldest abandoned terrace deposits along the Pacoima Wash. However, our initial ^{10}Be results indicate an average surface age of 29,540 ± 458 yrs, much younger than anticipated. Using the maximum vertical separation of 7 m across scarp 4 and 8.5 m across scarp 5 and a minimum surface age of 29,540 ± 458 years yields a minimum uplift rate of 0.52 ± 0.04 mm/yr for the entire surface. Assuming a 45˚ dipping fault plane and minimum uplift rate of 0.52 ± 0.04 mm/yr suggests a slip rate of 0.74 ± 0.13 mm/yr across the Lopez fan surface.

Wilson Canyon Fan

The Wilson canyon fan surface consists of a series of coalescing sand and gravel shed from several small drainages along the southern flank of the San Gabriel Mountains during the late Pleistocene. The northern extent of the fan surface is bound by the older, north-dipping Hospital fault, which marked the southern limit of crystalline bedrock (Figure 4). To the south, the Wilson Canyon fan is marked by a topographic inflection, forming a southward-facing scarp, informally termed the Wilson Canyon fault. Due to extensive dissection of the original fan surface, our topographic profile (Figure 4) incorporates two bends that allow for a more accurate measurement of the true vertical separation. The total vertical separation across the Wilson canyon escarpment is 63 ± 5 m. This value represents a minimum vertical separation because the Wilson Canyon fan surface is buried beneath the modern alluvium on the footwall block.

Using equally weighted samples yields a mean surface age of 52,930 ± 621 yrs. Although, if the sample ages are compared to its relative degree of weathering, younger samples correlate with a higher degree of weathering, indicating that the mean surface age likely underestimates the true surface age. A better estimate of the true surface age was obtained from the three quartz-rich samples (WC-14, 16 and 18) with the lowest degree of weathering that yields a mean surface age of 65,355 ± 1049 yrs. Using a 63 ± 5 m of vertical separation and a surface age 65,355 ± 1049 yrs gives an uplift rate of 1.07 ± 0.03 mm/yr across the Wilson Canyon fault. Assuming a 61°, fault dip, similar the Veterans fault, yields a slip rate of 1.2 ± 0.14 mm/yr across the Wilson Canyon fault.

Day Canyon Fan (Cucamonga fault)

We have also sampled, processed, and analyzed cobbles from the Day Canyon fan, which is offset by the Cucamonga fault (Figure 5). We provide new slip rates for the Cucamonga fault zone near Day Canyon based on 36 m of cumulative vertical separation across multiple fault scarps (Figure 6) and mean surface ages determined using modern cosmic-ray exposure dating methods. Cosmogenic surface dating of quartz-rich alluvial cobbles from the Qyf1a surface (West Fan of Morton and Matti, 1987) yielded a mean surface age 34,561 ± 328 years (Figure 7a).

To the east, seven quart-rich cobbles from the Qyf1b surface (East Fan of Morton and Matti, 1987) yields a mean cosmogenic surface age of 25,279 ± 395 years (Figure 7b). The surface ages for the Qyf1 surfaces are substantially older than the ~13 ka estimate of Morton and Matti (1987). The difference is likely due either to the large uncertainty associated with soil age comparisons or to the lack of a well constrained correction for inheritance among samples used for cosmogenic dating. The quartz-rich samples were collected only a short distance from the range front, suggesting a relatively short transport history that provides little time for a significant buildup of nuclide inheritance. Therefore, we interpret the mean surface age estimated using ^{10}Be cosmogenic dating is more representative of the true surface age than the soil ages.

During the past year, we produced digital elevation models (DEMs) using the early 1920's USGS 6-minute topographic map series (5 foot contour intervals). INTEC Americas Corporation produced 400 dpi 8-bit cropped geo-referenced scans of the following USGS 6-minute topographic maps, (1) 1927 Pacomia (surveyed 1924-1925), (2) 1939 Little Tujunga (surveyed 1933-1934), (3) 1942 Sunland (surveyed 1924-1925 and 1933), and (4) 1935 Sylmar (surveyed in 1925 and 1929). Our detailed maps of fault scarps and Quaternary geomorphic surfaces from the Pacomia area use these 5 m DEMs as a basemap.

Non-technical summary

This project is designed to determine slip rates across the Sierra Madre fault system, a key element in forecasting future seismic activity and accurately mapping seismic hazards. These data will help us to better understand how strain is accumulated and released on reverse faults in the greater metropolitan Los Angeles region.

Reports Published

We are in the process of final analyses and preparation of manuscript for publication.

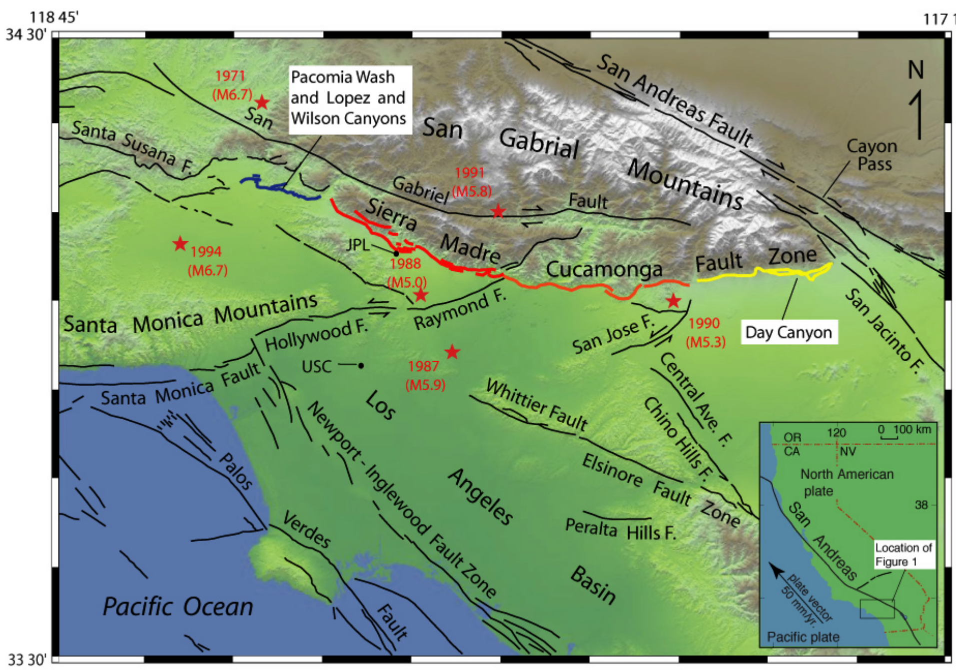

Figure 1. Fault map of southern California showing field locations, major faults and selected earthquake epicenters since 1971. The Sierra Madre-Cucamonga fault zone is colored; the 1971 surface rupture along the San Fernando segment is shown in blue, the central Sierra Madre segment is shown in red, the eastern segment is shown in orange and the Cucamonga segment is shown in yellow. Fault map from Crook et al. (1987) and Jennings (1994).

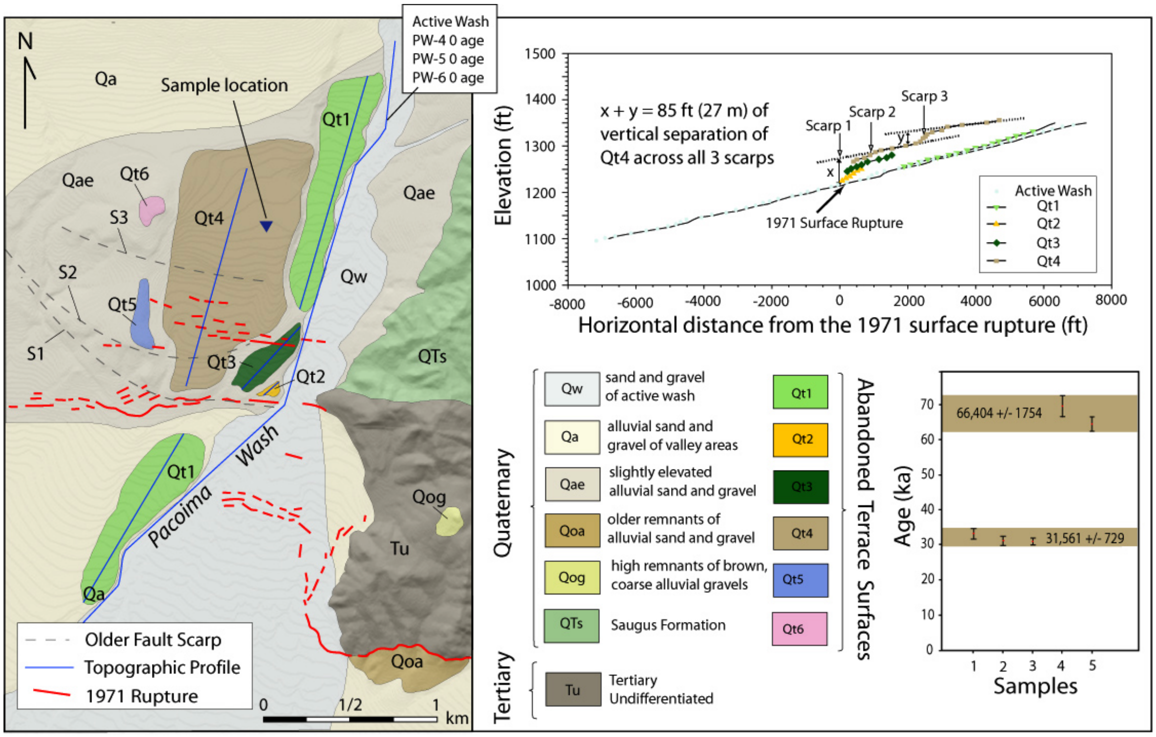

Figure 2. Abandoned alluvial terrace surfaces at Pacoima Wash along the 1971 surface rupture of the San Fernando earthquake. The 1971 rupture and additional fault scarps collectively displace Qt2 - Qt6 alluvial surfaces. Topgraphic profiles across the active Pacoima Wash and late Quaternary alluvial surfaces record about 27 m of vertical separation across the Qt4 terrace surface. Faults and geology modified from Dibblee (1991a), Kamb et al. (1971) and Barrows et al. (1975).

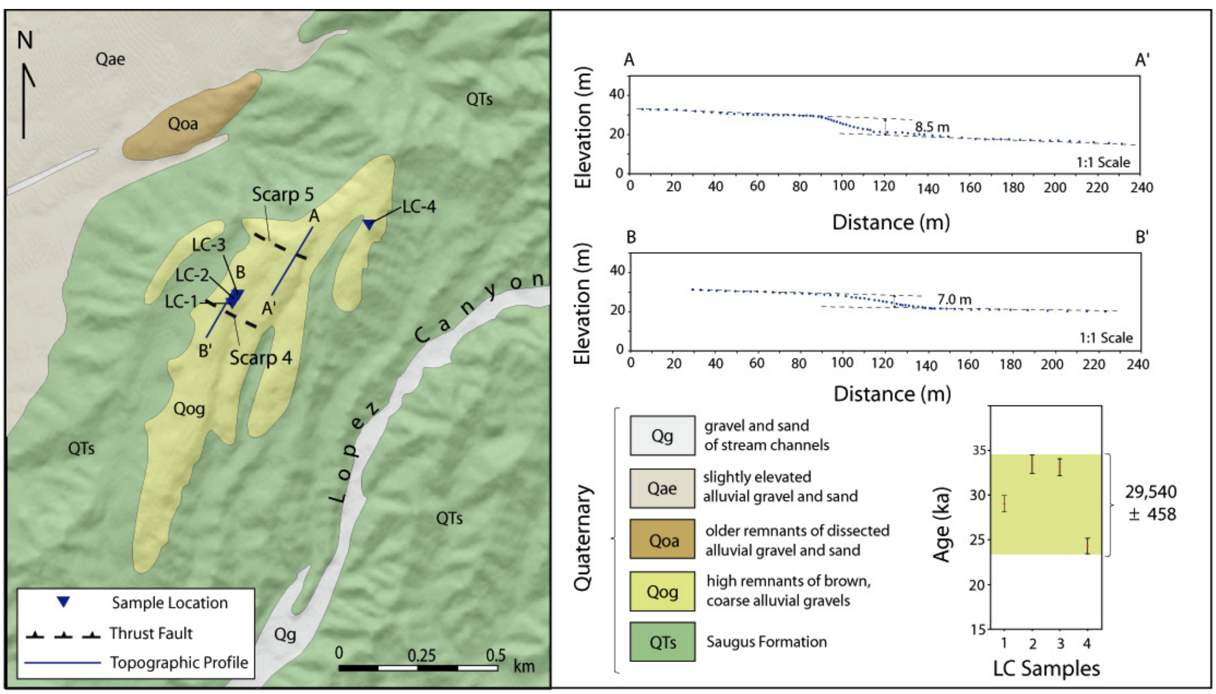

Figure 3. Geologic map of abandonded fan surface west of Lopez canyon showing topographic profile and sample locations. Topographic profiles were constructed from detailed surveys and show a cummulative surface offset across fault scarps 4 and 5 of 15.5 ± 1 meters. Surface samples yield a wieghted mean surface age of 29,540 ± 458 years. Geology modified from Dibblee (1991) and Wills and Hitchcock (1999).

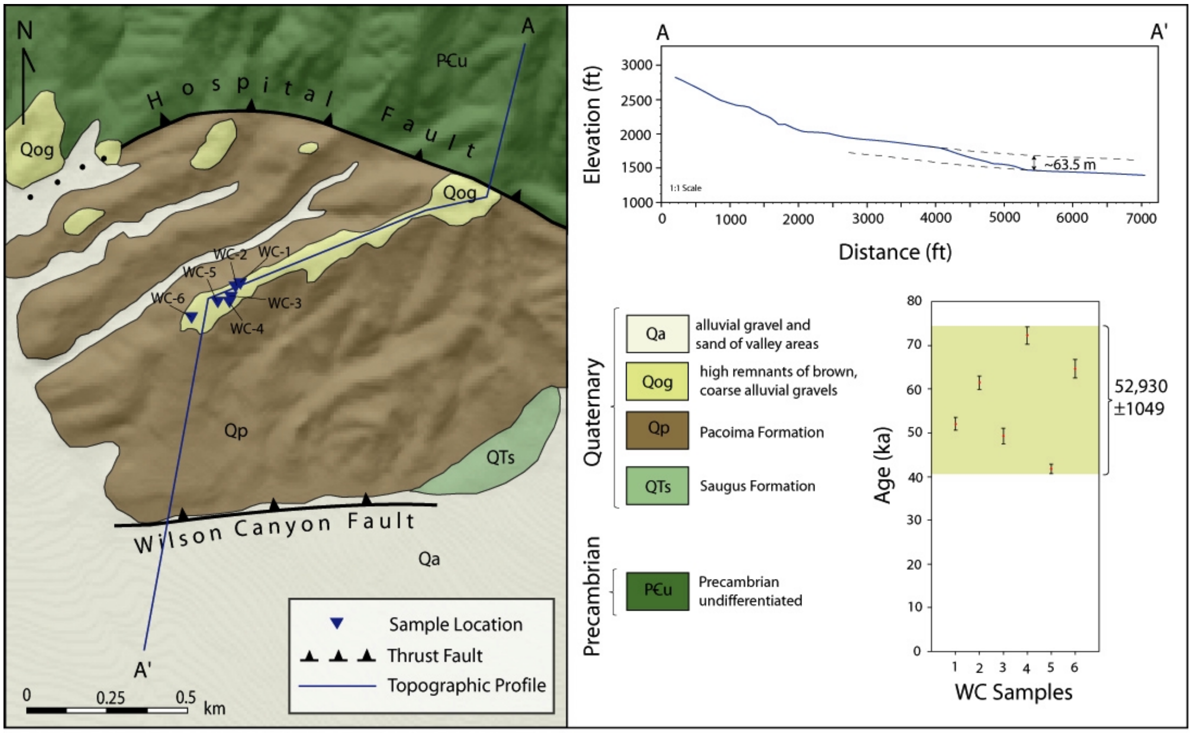

Figure 4. Geologic map of abandonded fan surface near Wilson Canyon showing topographic profile and sample locations. Topographic profiles were constructed using 5-20 ft contour maps and show a cummulative surface offset across the Wilson Canyon fault (informally named) of ~63.5 ± 5 m. Surface samples yield a wieghted mean surface age of 52,930 ± 458 years. Geology modified from Dibblee (1991) and Wills and Hitchcock (1999).

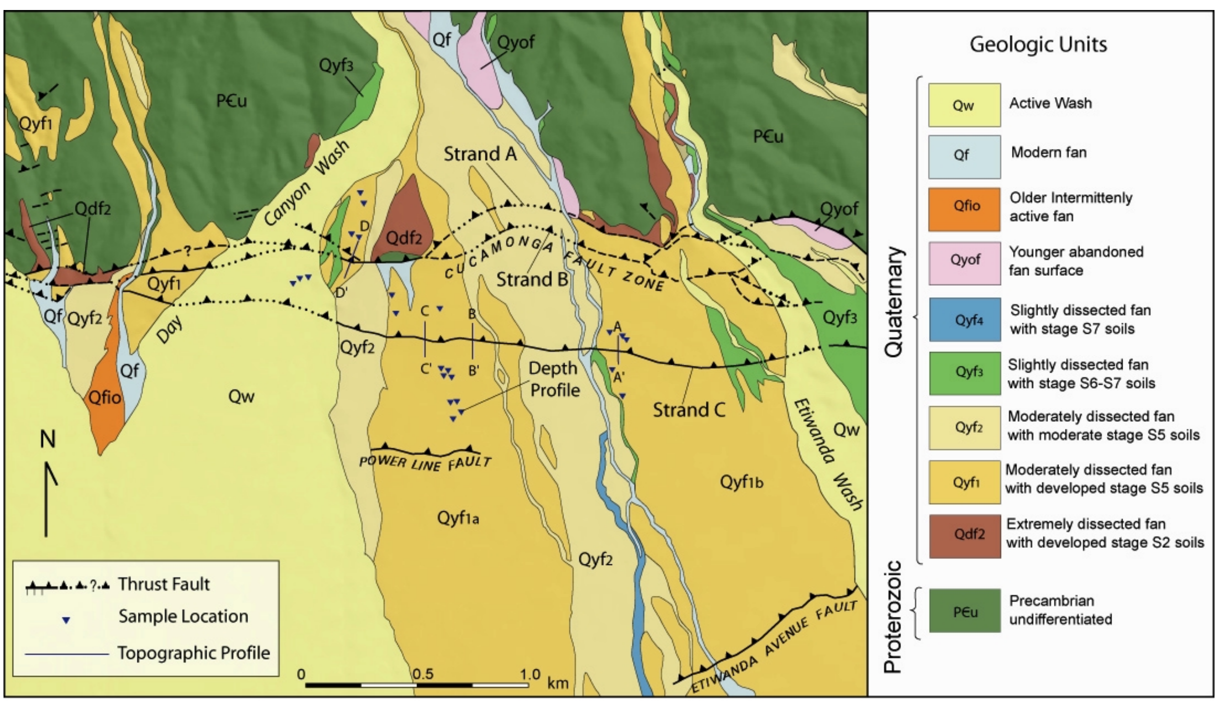

Figure 5. Geologic map of the Day Canyon Fan showing location of samples and topographic profiles. Faults and geology modified from Morton and Matti (1987).

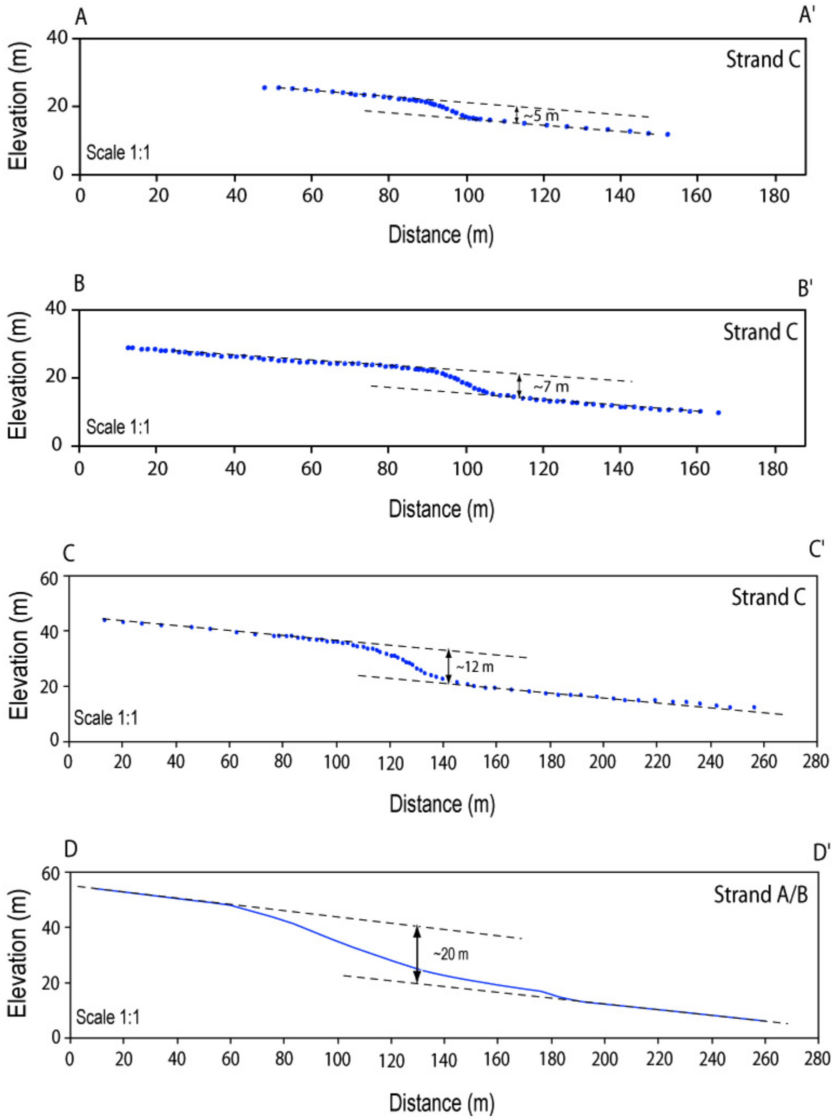

Figure 6. Topographic profiles across fault strands A/B and C along the Cucamonga fault zone near Day Canyon. Blue dots represent points surveyed using electronic total station and blue line represents surface profile constructed using topographic maps with 4 ft contour intervals. Profiles A, B and C illustrate the varriability in scarp height along strike for strand C. Matti et al. (1982) document a maximum scarp height of 16 m for strand C near Day Canyon, totaling 36 m of vertical seperation across unit Qyf1a. Profile locations are shown as blue lines in Figure 5.

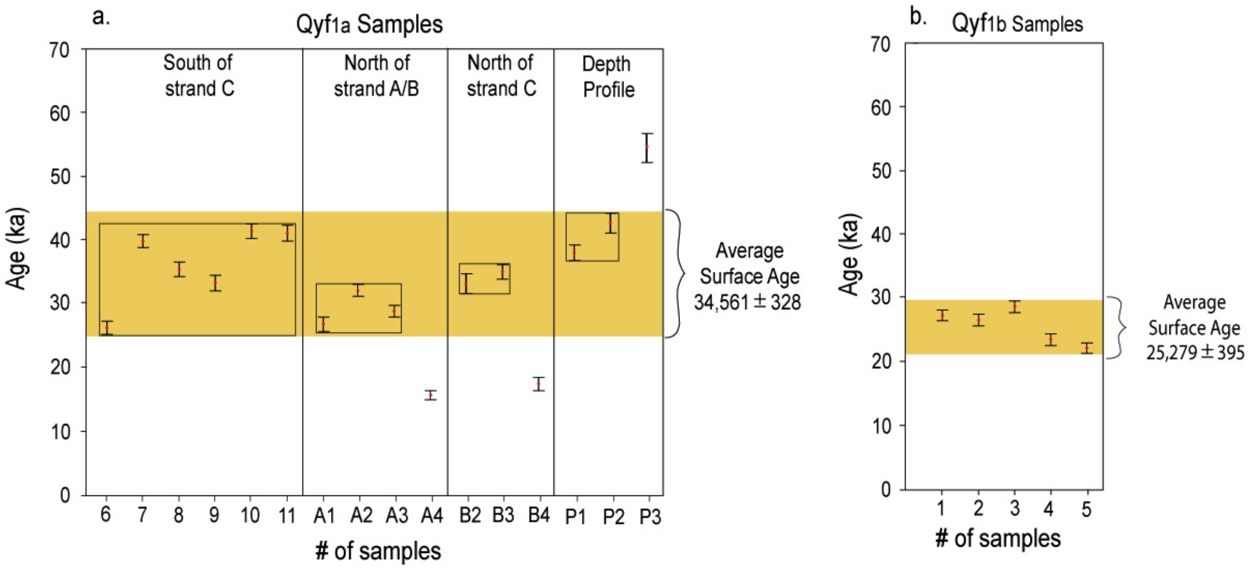

Figure 7. a. Model ages calculated for samples from unit Qyf1a on the west Day Canyon Fan. Average surface age is a weighted mean of 10Be model ages, excluding samples that plot outside the colored box. b. Model ages calculated for samples collected from unit Qyf1b on the east Day Canyon Fan. Error bars represent propogated uncertainties including 20% uncertainty on the production rate. Average surface age is a weighted mean of 10Be model ages, excluding samples that plot outside the colored box.